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Lecky

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(54) **PICK VERIFICATION USING MOVING RFID TAGS**

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G06F 17/00 (2006.01)
G06K 7/10 (2006.01)

(52) **U.S. Cl.**
CPC ***G06K 7/10366*** (2013.01); ***G06K 7/10128*** (2013.01)

(58) **Field of Classification Search**
CPC .. G06Q 10/08; G06Q 10/0833; G06Q 10/087; G06Q 10/0875; G06K 7/10108; G06K 7/10118; G06K 7/10128
See application file for complete search history.

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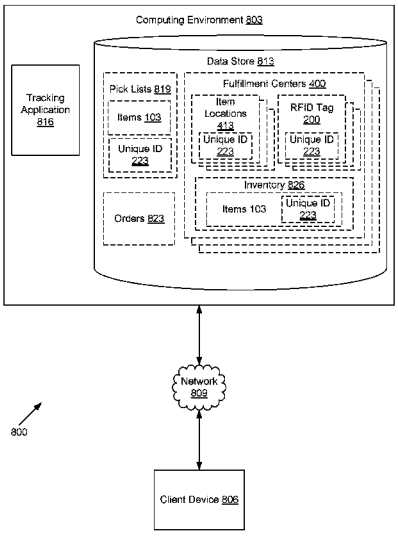
(57) **ABSTRACT**

Disclosed are various embodiments for pick verification using moving radio frequency identification (RFID) tags. A robotic picker moves an item storage structure within range of a radio frequency identification (RFID) tag reader, wherein the item storage structure comprises multiple items and the items each have an RFID tag affixed. The RFID tag reader emits an electric field. The robotic picker moves the item storage structure while the RFID tag reader emits the electric field. An RFID tag identification device receives responses from energized RFID tags affixed to the items. The RFID tag identification device determines that an energized RFID tag is in motion and selects an identifier broadcast by the energized RFID tag that is in motion.

20 Claims, 12 Drawing Sheets



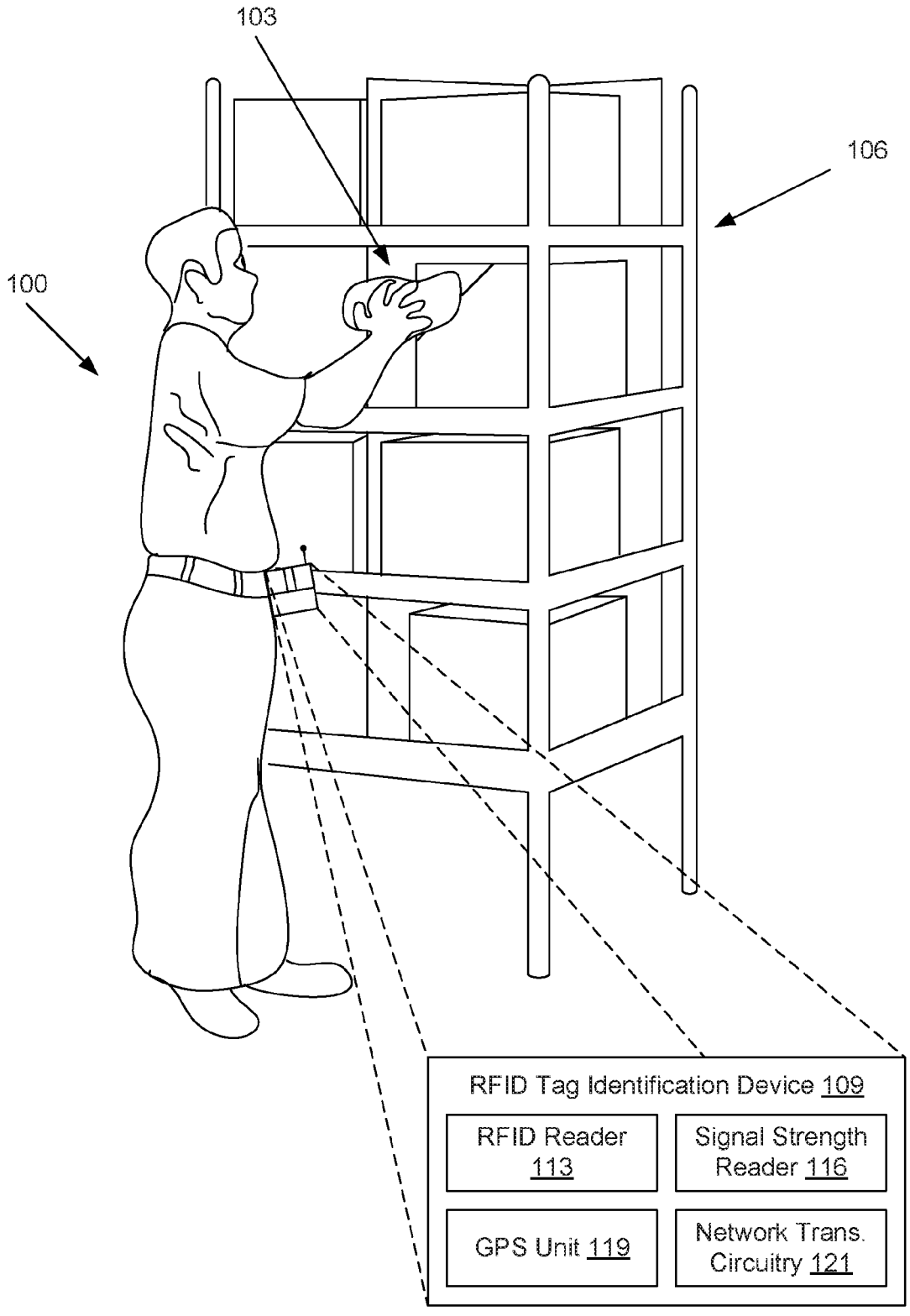

103
106
100
RFID Tag Identification Device 109
RFID Reader 113
Signal Strength Reader 116
GPS Unit 119
Network Trans. Circuitry 121

FIG. 1A

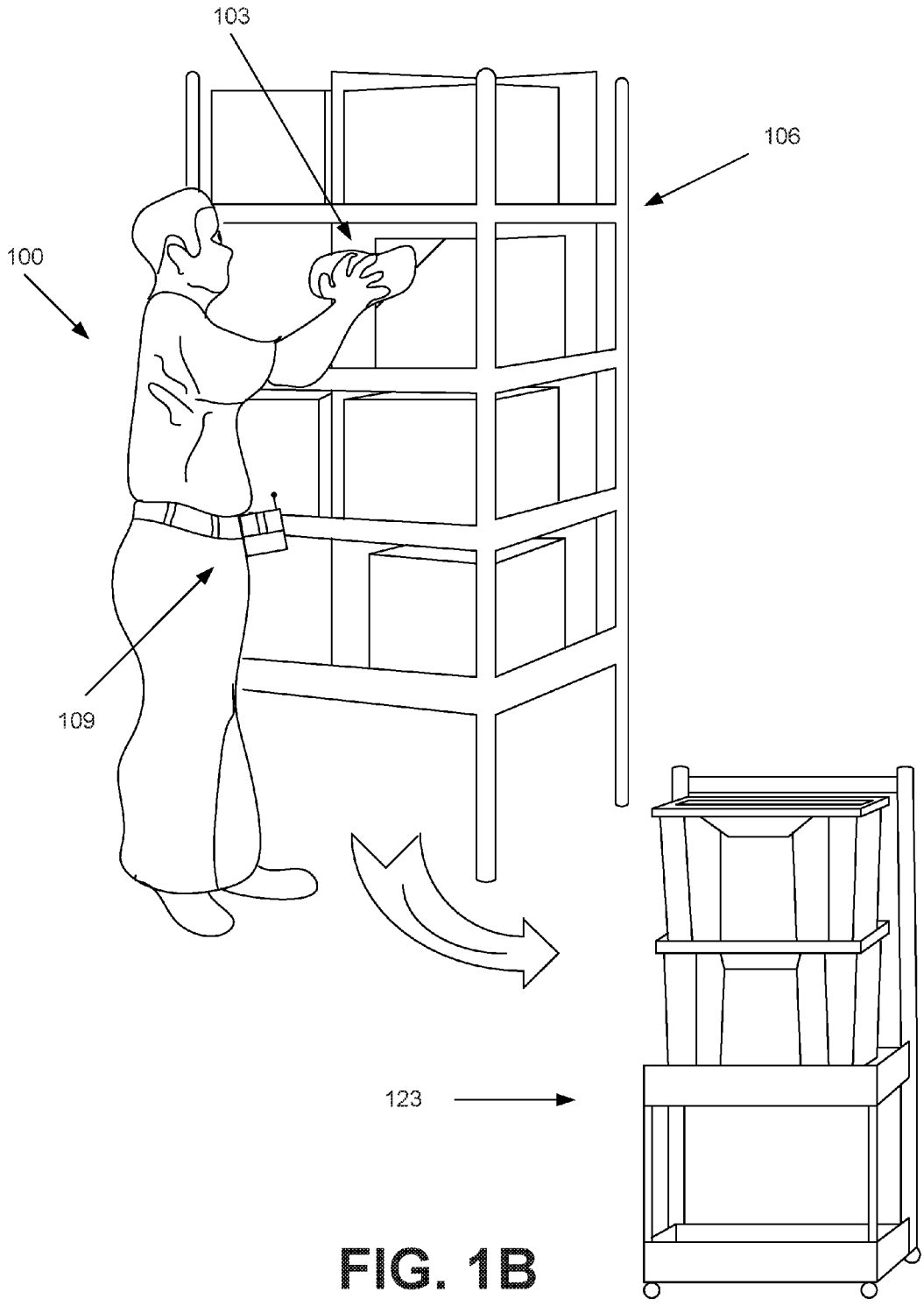


FIG. 1B

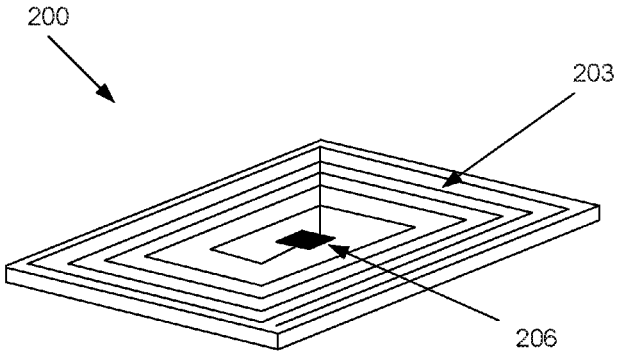

200
203
206

FIG. 2A

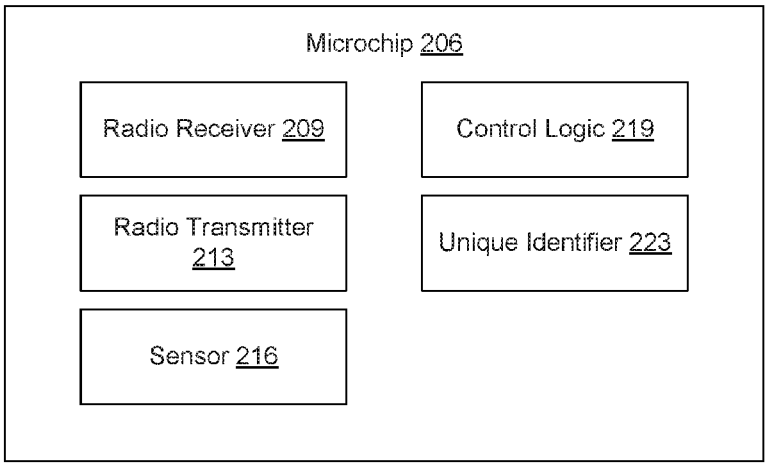

Microchip 206
Radio Receiver 209
Control Logic 219
Radio Transmitter 213
Unique Identifier 223
Sensor 216

FIG. 2B

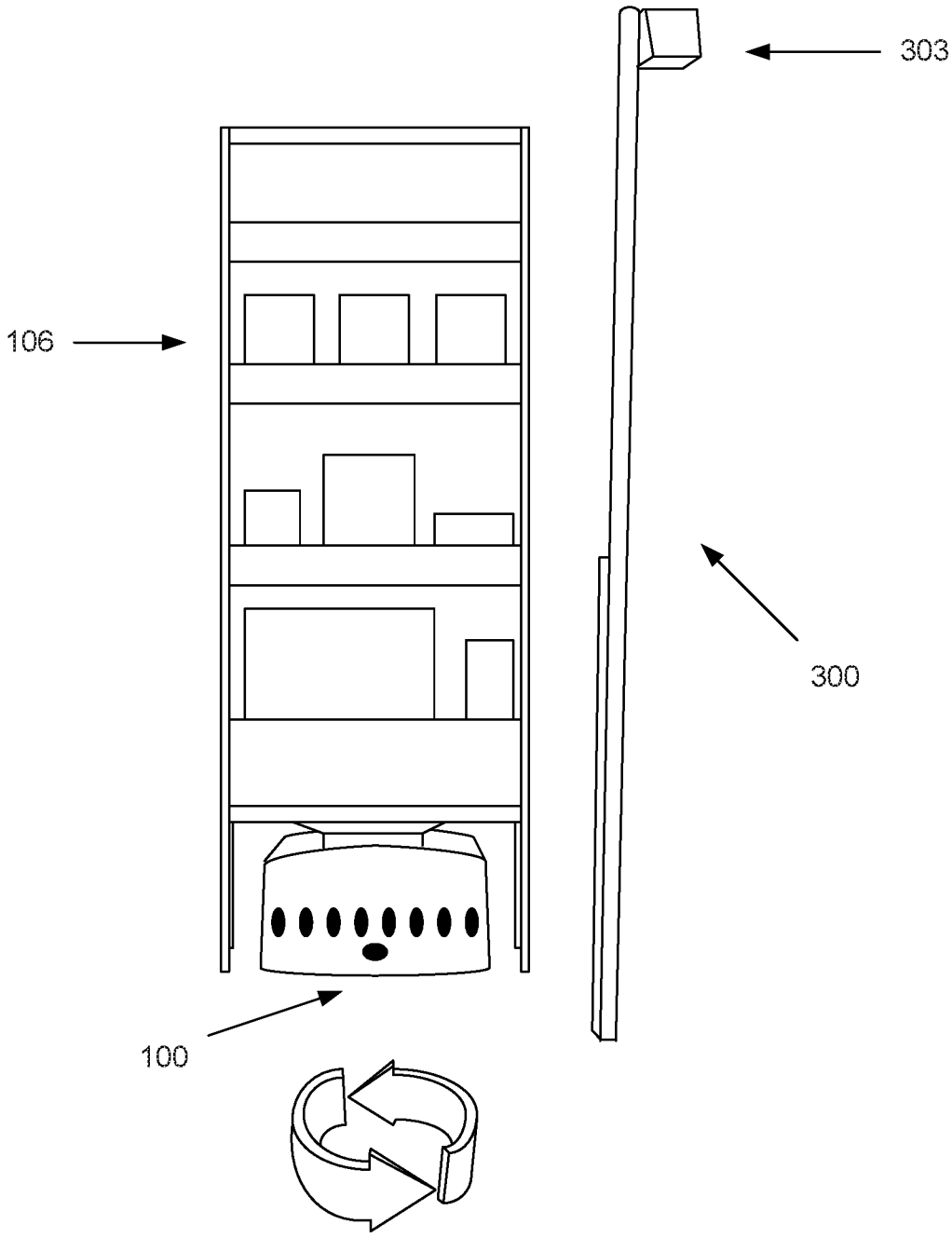


FIG. 3

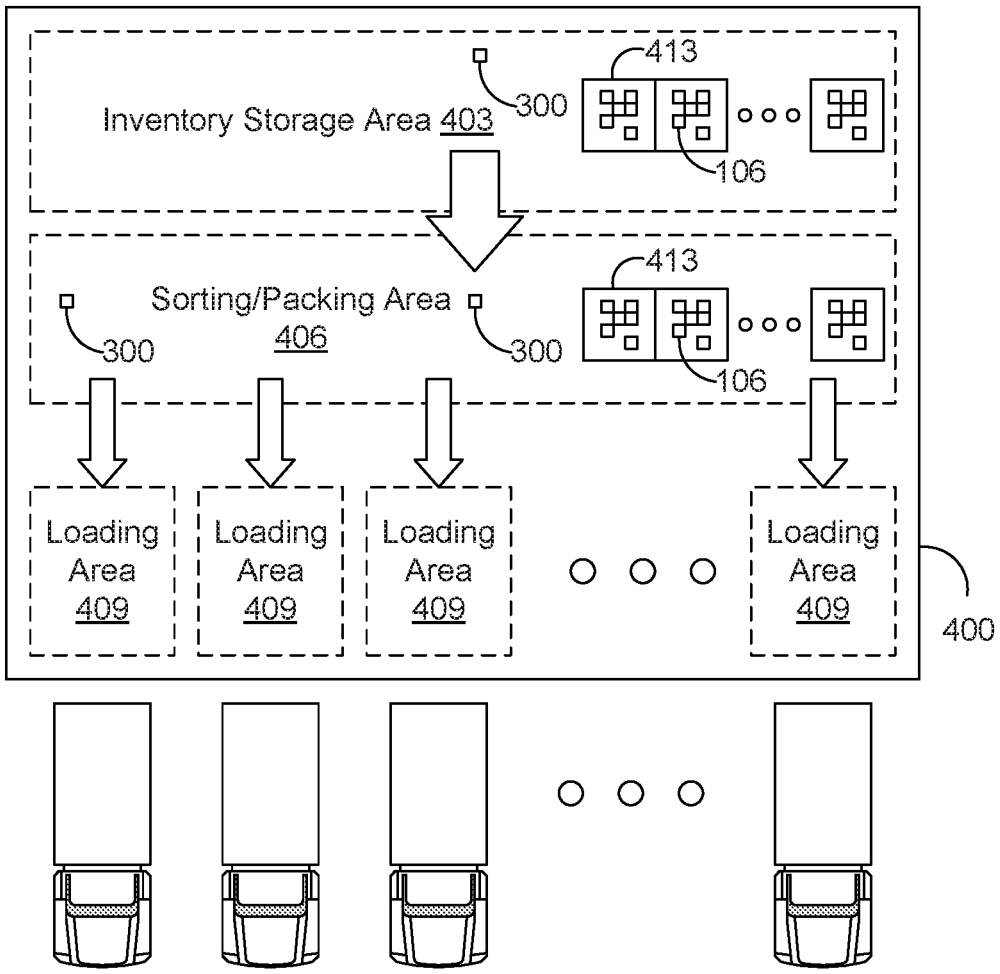

Inventory Storage Area 403
300
413
106
Sorting/Packing Area
406
300
300
413
106
Loading Area 409
Loading Area 409
Loading Area 409
Loading Area 409
400

FIG. 4

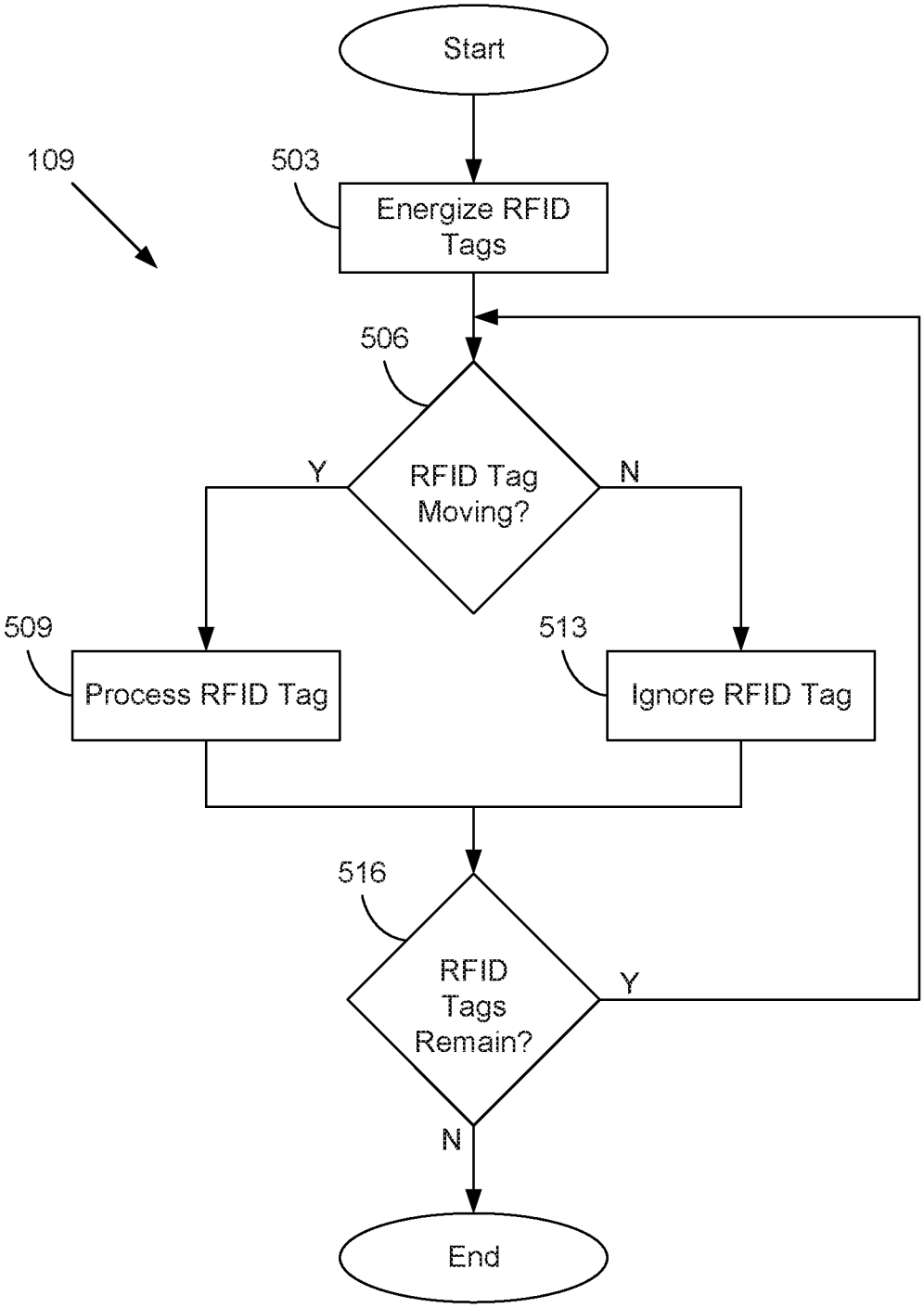

Start
109
503
Energize RFID Tags
506
RFID Tag Moving?
Y
N
509
Process RFID Tag
513
Ignore RFID Tag
516
RFID Tags Remain?
Y
N
End

FIG. 5

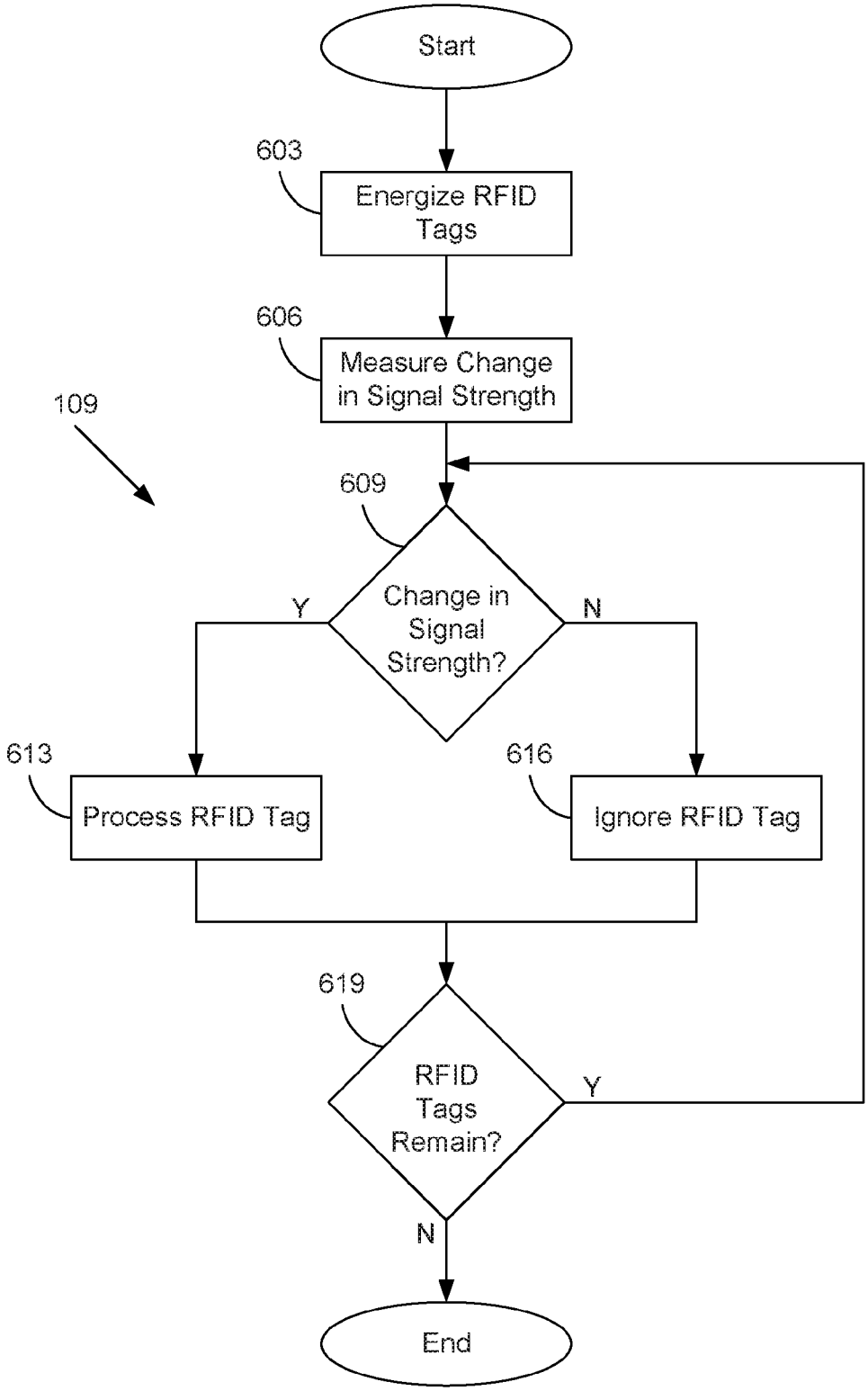

Start
603
Energize RFID Tags
606
Measure Change in Signal Strength
109
609
Change in Signal Strength?
Y
N
613
Process RFID Tag
616
Ignore RFID Tag
619
RFID Tags Remain?
Y
N
End

FIG. 6

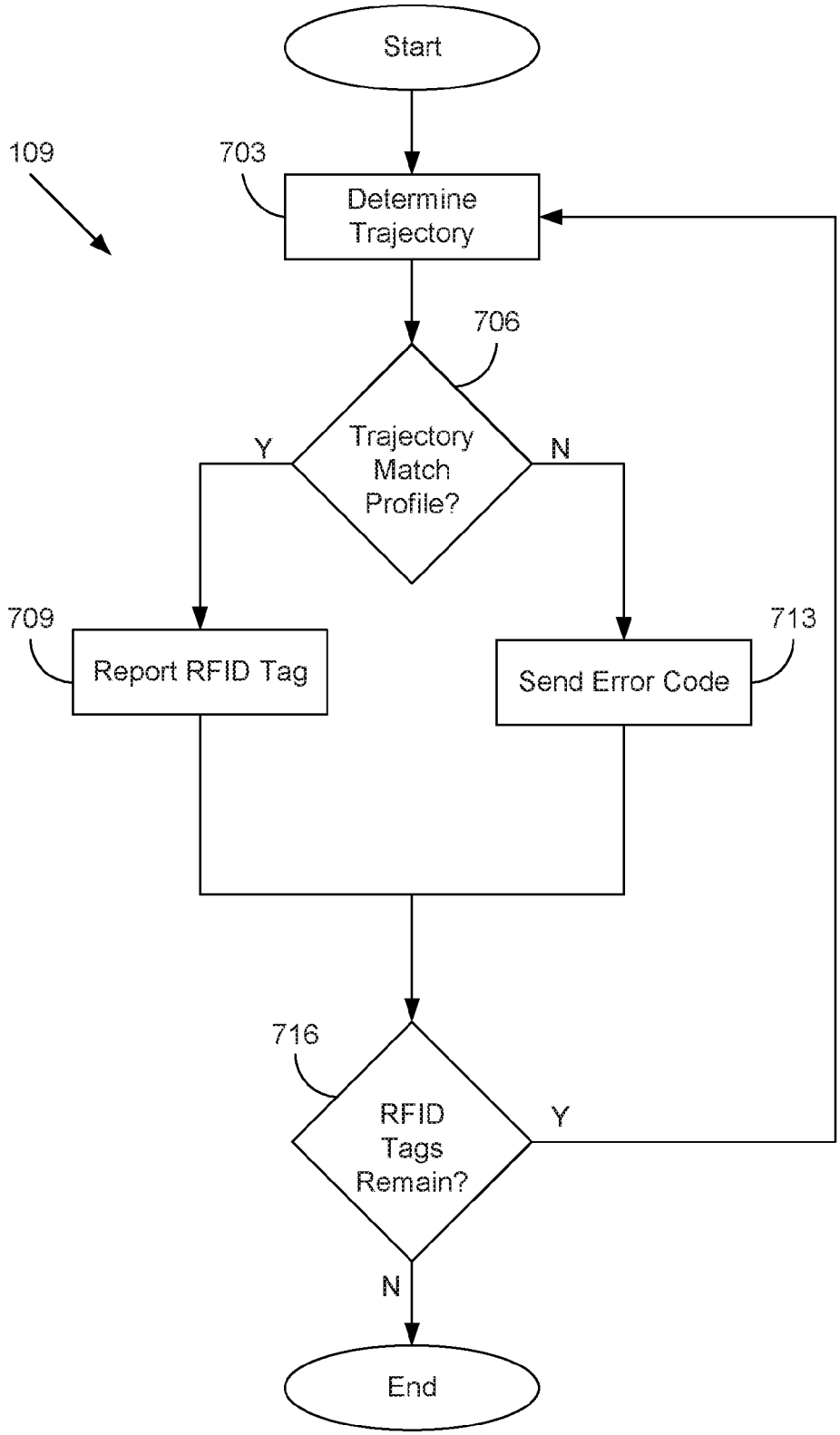

Start
109
703
Determine Trajectory
706
Trajectory Match Profile?
Y
N
709
Report RFID Tag
713
Send Error Code
716
RFID Tags Remain?
Y
N
End

FIG. 7

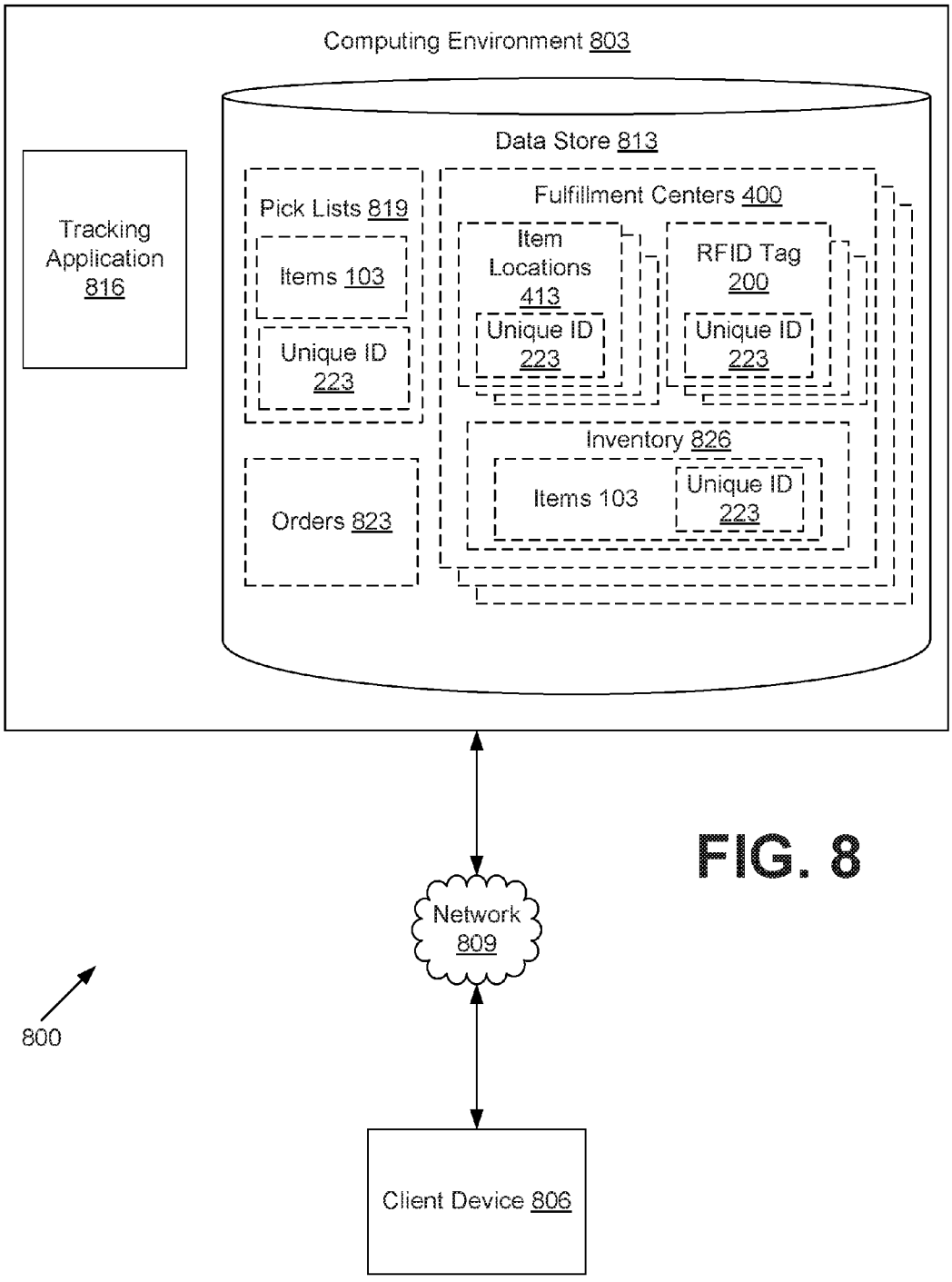

Computing Environment 803
Data Store 813
Tracking Application 816
Pick Lists 819
Items 103
Unique ID 223
Fulfillment Centers 400
Item Locations 413
Unique ID 223
RFID Tag 200
Unique ID 223
Inventory 826
Items 103
Unique ID 223
Orders 823
Network 809
800
Client Device 806

FIG. 8

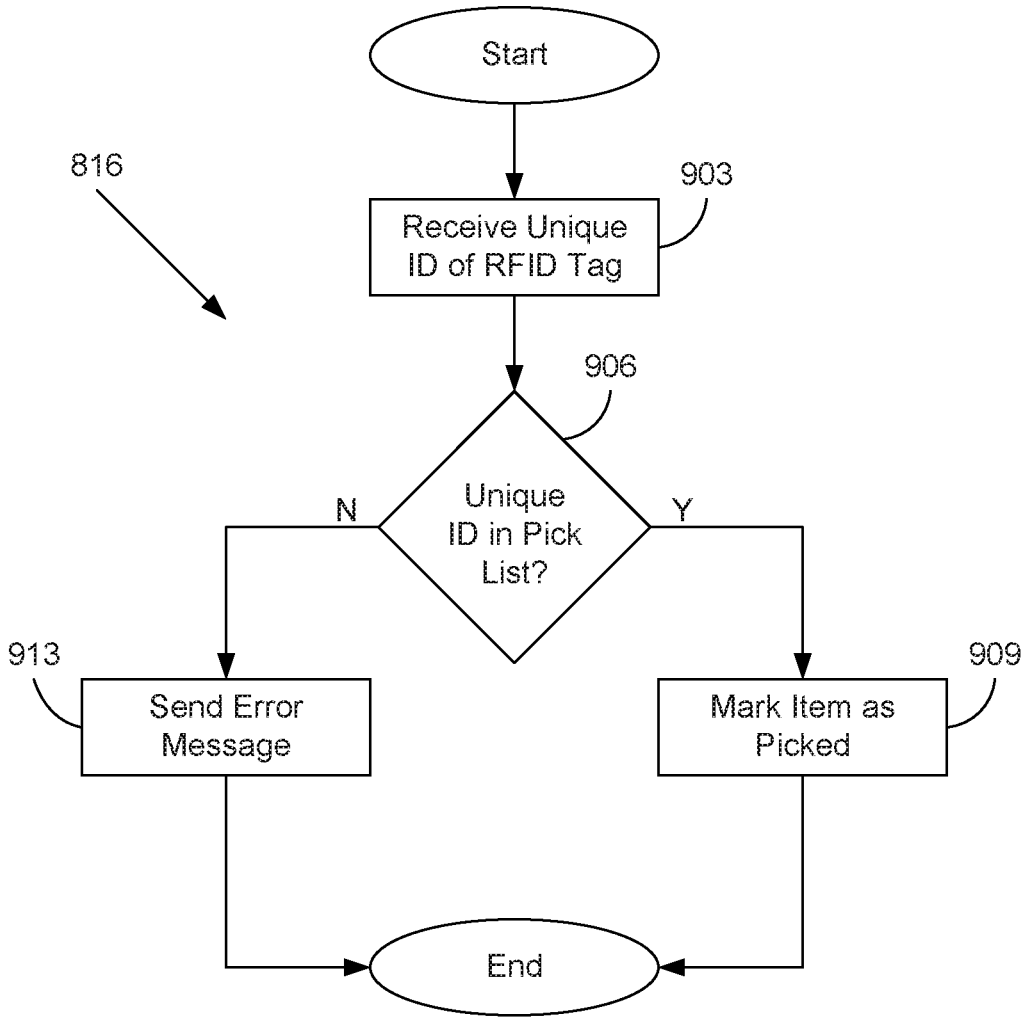

Start
816
903
Receive Unique ID of RFID Tag
906
Unique ID in Pick List?
N
Y
913
Send Error Message
909
Mark Item as Picked
End

FIG. 9

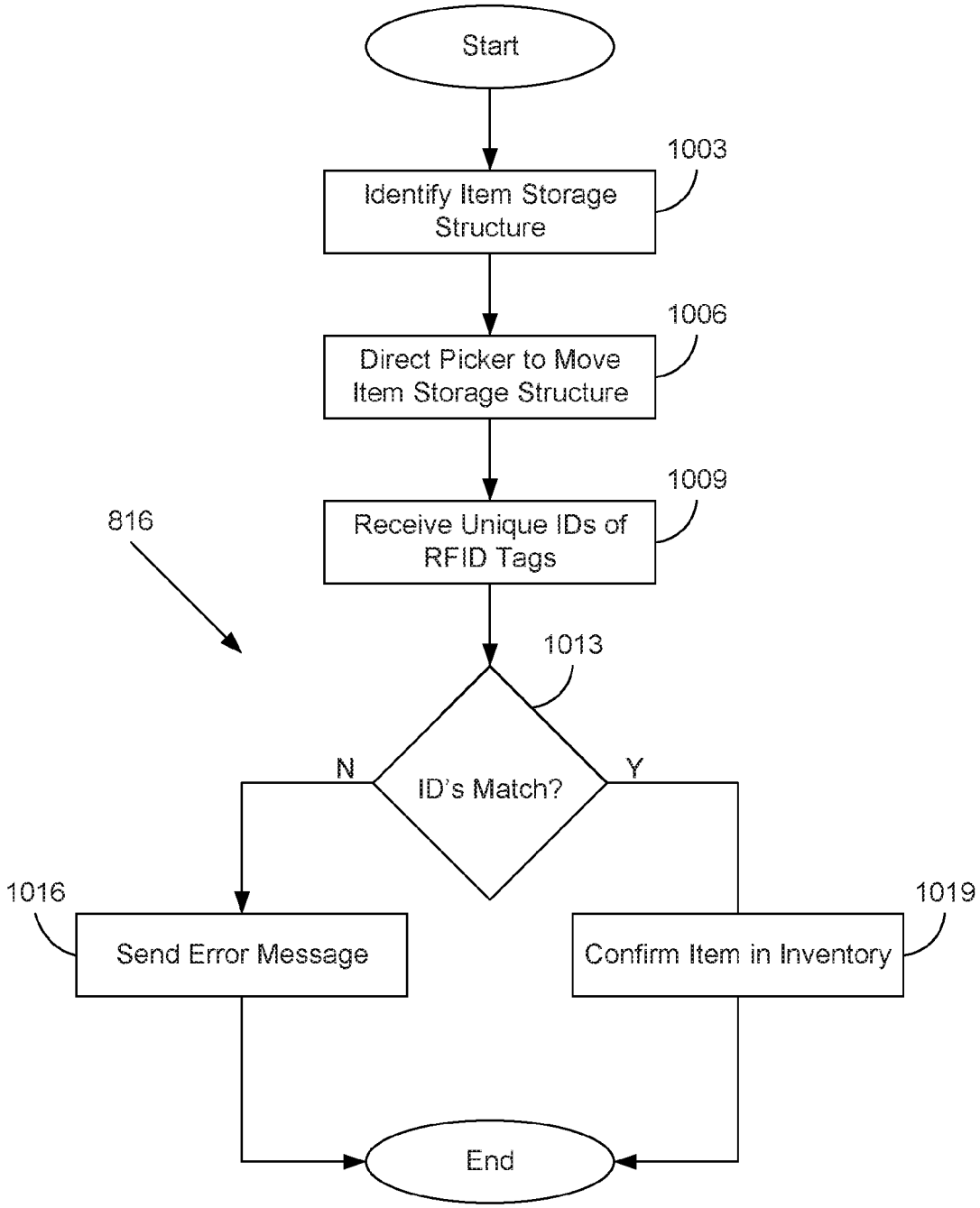

Start
1003
Identify Item Storage Structure
1006
Direct Picker to Move Item Storage Structure
1009
Receive Unique IDs of RFID Tags
816
1013
N
ID's Match?
Y
1016
Send Error Message
1019
Confirm Item in Inventory
End

FIG. 10

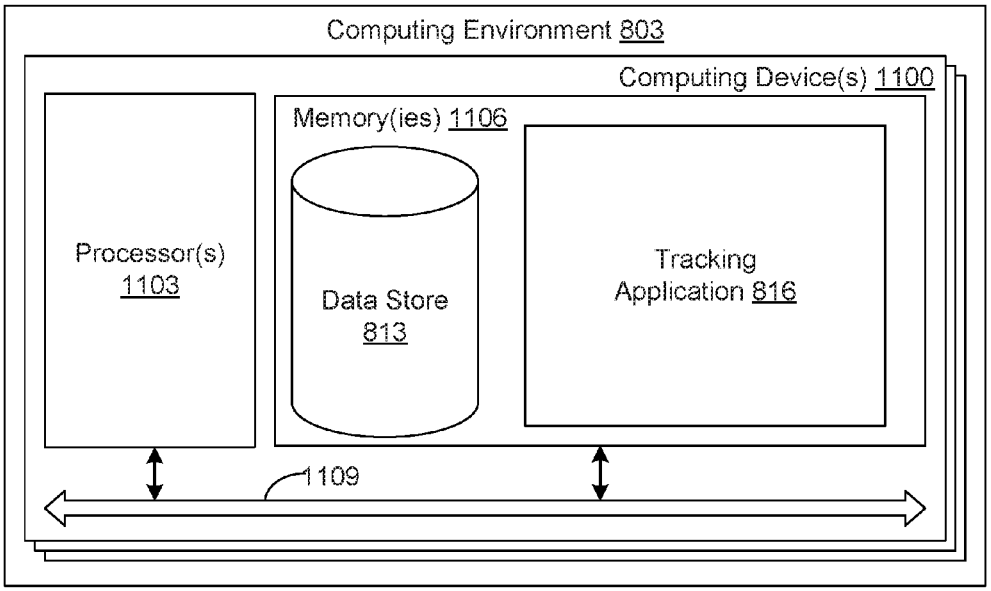

Computing Environment 803
Computing Device(s) 1100
Memory(ies) 1106
Processor(s) 1103
Data Store 813
Tracking Application 816
1109

FIG. 11

PICK VERIFICATION USING MOVING RFID TAGS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a division of copending U.S. patent application Ser. No. 14/467,760, entitled "DISTINGUISHING RFID TAGS USING MOTION DATA" and filed on Aug. 25, 2014, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

Shipments of items are often assembled and fulfilled from distribution or fulfillment centers where the items are stored. Items are retrieved from the inventory located at the distribution or fulfillment center by employees, packed, and shipped. Items in the inventory in the distribution or fulfillment center may be stored in one or more locations within the distribution or fulfillment center.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1**A is a drawing depicting a picker retrieving an item from a storage location and a schematic block diagram illustrating a RFID tag identification device of the picker.

FIG. **1**B is a drawing depicting the motion of a picker retrieving an item from a storage location.

FIG. **2**A is a drawing of a radio frequency identification (RFID) tag according to various embodiments of the present disclosure.

FIG. **2**B is a schematic block diagram of an integrated circuit included in the RFID tag of FIG. **2**A according to various embodiments of the present disclosure.

FIG. **3** is a drawing of a robotic picker verifying inventory at an item storage location in a fulfillment center according to various embodiments of the present disclosure.

FIG. **4** is a drawing of a fulfillment center according to various embodiments of the present disclosure.

FIG. **5** is a flowchart illustrating one example of functionality implemented as portions of the RFID tag identification device of FIG. **1**A according to various embodiments of the present disclosure.

FIG. **6** is a flowchart illustrating one example of functionality implemented as portions of the RFID tag identification device of FIG. **1**A according to various embodiments of the present disclosure.

FIG. **7** is a flowchart illustrating one example of functionality implemented as portions of the RFID tag identification device of FIG. **1**A or, in some embodiments, the RFID reader station depicted in FIG. **3** according to various embodiments of the present disclosure.

FIG. **8** is a drawing of a networked environment according to various embodiments of the present disclosure.

FIG. **9** is a flowchart illustrating one example of functionality implemented as portions of an application executed in a computing environment in the networked environment of FIG. **8** according to various embodiments of the present disclosure.

FIG. **10** is a flowchart illustrating one example of functionality implemented as portions of an application executed in a computing environment in the networked environment of FIG. **8** according to various embodiments of the present disclosure.

FIG. **11** is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. **8** according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

The present disclosure involves various embodiments for verifying, with various radio frequency identification (RFID) devices, that items in a distribution or fulfillment center have been correctly retrieved for fulfillment of an order. A fulfillment center may be any one of a number of material handling facilities, such as a warehouse, distribution center, or similar facility. When fulfilling a given shipment corresponding to a customer order, one or more pickers on pick routes stop at item locations mapped to the shipment to retrieve the items to be shipped. In various embodiments, some items retrieved by a picker may have a corresponding RFID tag. In some embodiments, the picker may also be equipped with an RFID tag identification device, which may be used to read the RFID tag in order to verify that an item retrieved by the picker is the correct item for fulfilling the shipment for the customer order and/or read the RFID tag for other purposes. However, the RFID tag identification device may, in some embodiments, be attached to a cart, hand truck, forklift, or other apparatus which the picker may move while retrieving items. In other embodiments, one or more stationary RFID tag identification devices may be located throughout the fulfillment center. Stationary RFID tag identification devices may be located near one or more item locations to track and monitor RFID tags at the item locations. In various embodiments, a picker may also be equipped to move a bin, pallet, set of shelves, and/or other item storage structure to an RFID reader station, where all of the RFID tags within the item storage location may be read to verify inventory accuracy.

In some embodiments, individual RFID tags may be identified based on motion data transmitted by the individual RFID tags. Each of the RFID tags may have an accelerometer, velocimeter, or other instrument that reports a speed, acceleration, direction of movement, current position, and/or other such data. For example, multiple RFID tags may be energized by an RFID reader or RFID tag identification device and broadcast data, such as a unique identifier of the RFID tag and/or motion data of the RFID tag, in response to being energized. However, the motion data can be used to isolate an RFID tag from the remaining RFID tags for further analysis.

As an illustrative and non-limiting example, multiple items with RFID tags may be in proximity to each other. A picker, as discussed above, may retrieve an item and scan it with an RFID reader. However, both the retrieved items and the other items may transmit in response to being scanned and energized by the RFID reader. But by analyzing motion data broadcast by each of the RFID tags, the RFID tag corresponding to the item that has been retrieved by the picker may be uniquely identified. For example, if only a single RFID tag reports motion data, then the item corresponding to the moving RFID tag may be identified as having been retrieved by the picker. As another example, if multiple RFID tags report motion, such as both the item that has been picked and other items that have been shifted,

adjusted, nudged and/or jostled in the process, then an RFID tag reporting motion data that matches an expected trajectory of an item being picked may be identified as having been retrieved by the picker. Motion data reported may also be used to isolate and/or identify individual RFID tags in other scenarios, as will be further described herein, including, but not limited to, detecting if an item has been dropped, stolen, and/or misplaced.

In some embodiments, individual RFID tags may also be identified based on changes in the strength of the signal transmitted by the RFID tag. As an RFID tag moves towards or away from a point in space, such as that of an RFID reader, the signal strength of a transmission of the RFID tag will increase or decrease in strength. Further, particular types of motion may correspond to a particular pattern of increases and decreases in signal strength. As illustrative example, the signal strength of an RFID tag of an item moving laterally to an RFID reader may first increase in strength as the item approaches the RFID reader and then decrease in strength as the item moves away from the RFID reader. As another illustrative example, a signal strength for an RFID tag may increase in strength as the RFID tag moves towards the RFID reader. These changes in signal strength can be used to isolate an RFID tag from other RFID tags for further analysis.

As an illustrative and non-limiting example, multiple items with RFID tags may be in proximity to each other. A picker, as discussed above, may retrieve an item and scan it with an RFID reader. However, both the retrieved items and the other items may transmit in response to being scanned and energized by the RFID reader. By analyzing changes in the signal strength of the response of each of the RFID tags, the RFID tag corresponding to the item that has been retrieved by the picker may be uniquely identified. For example, although multiple RFID tags may show some change in signal strength as a result of being adjusted, shifted, nudged, or jostled when the picker retrieves an item, the RFID tag corresponding to the retrieved item may be the only RFID tag reporting a consistent and steady increase in signal strength over time, assuming the RFID reader is positioned with or near the picker. Changes in signal strength may also be used to isolate and/or identify individual RFID tags in other scenarios, as will be further described herein, including, but not limited to, detecting if an item has been dropped, stolen, and/or misplaced.

In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same. Although the description herein refers to various example embodiments, any example embodiments detailed herein are illustrative in nature. For example, various example embodiments related to picking are detailed herein, the present invention is applicable in other contexts, such as packing, stowing, and/or other materials handling, as well as other fields in which articles, items, and/or individuals may be distinguished from each other using motion data related to RFID tags.

FIG. **1**A is an illustration of a picker **100** retrieving an item **103** from an item storage structure **106**. Although the picker **100** depicted in FIG. **1**A is a human, it is understood that, in various embodiments, the picker **100** may be an autonomous robot or similar device with the ability to retrieve items **103** from an item storage structure **106**. The picker **100** has a RFID tag identification device **109**. In some embodiments, such as the embodiment depicted, the RFID tag identification device **109** may be attached to the picker **100**. In other embodiments, the RFID tag identification device **109** may be a handheld, portable, and/or detachable device. Further, the RFID tag identification device **109** may be attached to a cart, hand truck, forklift, or other apparatus associated with the picker **100**. In yet other embodiments, the RFID tag identification device may be a fixed, immobile device placed at a particular location, e.g., a picking station at which the picker **100** may retrieve the item **103** from the item storage structure **106**.

The RFID tag identification device **109** includes a radio frequency identification (RFID) reader **113** to read the unique identifier of an RFID tag attached to or otherwise associated with the item **103**. The RFID reader **113** included in the RFID tag identification device **109** may also be configured to receive additional information that may be transmitted by an RFID tag, such as motion vectors, acceleration data, and other such data. In some embodiments, the RFID tag identification device **109** may include a signal strength reader or meter **116** in addition to the RFID reader **113**. The signal strength reader **116** allows the RFID tag identification device **109** to determine the strength of a signal emitted by a nearby RFID tag. Moreover, the signal strength reader **116** may be used, in some embodiments, to determine whether a signal emitted by a nearby RFID tag is increasing or decreasing in strength based on a series of measurements made over a period of time. These increases or decreases may correspond to a radio transmission or series of radio transmissions of an RFID tag associated with the item **103** as the item **103** is retrieved by the picker **100** and is pulled closer to the picker **100**. In various embodiments, the signal strength reader **116** may make multiple measurements of the signals emitted by a nearby RFID tag within a short period of time, wherein the differences between each of the measurements over time is used to determine whether the signals emitted by the nearby RFID tag are increasing or decreasing in strength.

In some embodiments, the RFID reader **113** may be further configured to ignore RFID tags broadcasting with a signal strength below a configurable threshold. In such embodiments, ignoring RFID tags with weaker signals filters out RFID tags that a picker **100** may not wish to have scanned, but respond to signals from the RFID reader **113** due to their proximity to the RFID reader **113**. In some embodiments, the RFID tag identification device **109** may also include a global positioning system (GPS) unit **119** or similar circuitry. In these embodiments, the RFID tag identification device **109** is able to determine its location, which can be used to identify a particular item storage structure **106** based at least in part on the location of the RFID tag identification device **109** and/or other data, such as the item **103** that the picker **100** is picking.

The RFID tag identification device **109** may also include network transmission circuitry **121**. This network transmission circuitry **121** may include, for example, various wireless networking capabilities such as Bluetooth® or Wi-Fi® networking capabilities. In these embodiments, the RFID tag identification device **109** is able to transmit information to and receive data from remote computing devices. For example, the RFID tag identification device **109** may be configured to use the RFID reader **113** to read an RFID tag associated with the item **103** and transmit information from the RFID tag to a remote computing device, as will be described in further detail herein. The RFID tag identification device **109** may also be configured to receive data from the remote computing device in response to sending information from the RFID tag of the item **103**. Moreover, the network transmission circuitry **121** of the RFID tag identification device **109** may be used to triangulate the position

of the RFID tag identification device **109** in those embodiments that lack a GPS unit **119** or similar circuitry or when GPS signals or similar signals are unavailable.

The RFID tag identification device **109** may be positioned in various locations on the picker **100**. For example, the RFID tag identification device **109** may be positioned on the picker **100** in a manner to minimize or avoid any electromagnetic shadow or other interference created by the arm of the picker **100** with respect to an item **103** being retrieved by the picker **100**. Objects located between a transmitter and a receiver of a radio wave can create interference or shadow effects. In order to maximize the accuracy of a signal strength measured by the signal strength reader **116** within the RFID tag identification device **109**, the RFID tag identification device **109** may be positioned in order to avoid the picker **100** inadvertently placing an arm or other appendage between the RFID tag identification device **109** and the item **103** being retrieved.

Proceeding to FIG. **1**B, depicted is an example of a type of motion that may be identified using the RFID tag identification device **109**. Although the RFID tag identification device **109** is depicted as being attached to the picker **100**, other positions and locations for the RFID tag identification device **109** are possible, including stationary and/or stand along RFID tag identification devices **109**. Here, the picker **100** is moving an item **103** from an item storage structure **106** to a cart **123**. As previously discussed above and discussed in further detail herein, the illustrated trajectory of the motion of the item **103** from the item storage structure **106** to the cart **123** may detected and/or identified based at least in part one or more of changes in signal strength broadcast by an RFID tag attached to the item **103** as it moves relative to the RFID tag identification device **109** and/or motion data detected by a sensor in the RFID tag attached to the item **103** and transmitted or broadcast to the RFID tag identification device **109**.

Moving on to FIG. **2**A, shown is an example of an RFID tag **200**, which may be used in conjunction with the RFID tag identification device **109** according to various embodiments of the present disclosure. The RFID tag **200** may include a number of components, such as an antenna **203**, a microchip **206**, and other circuitry. Active RFID tags **200** may also include a battery to provide electrical power to the microchip **206** or to energize the antenna **203** for transmission. Passive RFID tags **200** do not include a battery and instead rely upon receiving an electromagnetic signal via the antenna **203** to remotely energize the passive RFID tags **200** for operation. In some embodiments, an RFID tag **200** may also include multiple microchips **206** and/or multiple antennas **203** to permit additional or advanced operations or to permit transmission and reception of radio signals on multiple frequencies. Although depicted as a flat, rectangular structure, RFID tags **200** may be constructed in any number of shapes or forms, depending on the particular application. For example, RFID tags **200** may be constructed in the form of a capsule, badge, or other form.

FIG. **2**B depicts a schematic block diagram of an embodiment of a microchip **206** that may be found in an RFID tag **200**. The microchip **206** may include, for example, a radio receiver **209**, a radio transmitter **213**, a sensor **216**, control logic **219**, and/or other circuitry. The microchip **206** may also store a unique identifier **223** of the RFID tag **200**, as well as other data.

The radio receiver **209** may, for example, convert an energizing electromagnetic signal into an electric charge suitable for use by the microchip **206**. The radio receiver **209** may also, for example, decode radio transmissions for processing by the control logic **219** or other circuitry. In such embodiments, the radio receiver **209** may include a front end receiver and baseband processor, among other related circuitry.

The radio transmitter **213** may, for example, transmit information pursuant to instructions received from the control logic **219**. For example, the radio transmitter may convert a unique identifier **223** into an appropriate radio transmission for broadcast pursuant to instructions received from the control logic **219**. In some embodiments, the radio transmitter **213** may correspond to a modem, baseband processor, or similar circuitry. In some embodiments, the radio transmitter **213** may also be configured to transmit, broadcast, and/or otherwise operate on a different frequency than the radio receiver **209** in order to minimize interference between the electromagnetic signal received from the RFID reader **113** (FIG. **1**A) and the electromagnetic signal emitted by the radio transmitter **213**.

In some embodiments, the microchip **206** of the RFID tag **200** may include a sensor **216**. For example, the sensor **216** may include one or more accelerometers, velocimeters, and/or other motion sensors. In such embodiments, the RFID tag **200** may detect whether it is accelerating as well as the direction of acceleration (e.g., along the X-axis, Y-axis, or Z-axis) and the magnitude of acceleration. In some embodiments, the magnitude of acceleration along each axis of movement may also be detected and/or recorded. In various embodiments, RFID tag **200** may detect the velocity (speed and direction) instead or in addition to the acceleration of the RFID tag **200**. Due to the generally small size of RFID tags **200**, one or more microelectromechanical systems (MEMS) sensors may be used. In certain embodiments, alternatively or in addition to MEMS accelerometers, one or more MEMS gyroscopes may be used.

Control logic **219** may be included in the microchip **206** of RFID tags **200** in order to provide RFID tags **200** with additional functionality. For example, the control logic **219** may allow for an RFID tag **200** to selectively broadcast. As an illustrative and non-limiting example, a passive RFID tag **200** may have control logic **219**, such as an electrical switch and/or a series of firmware instructions, configured to direct the RFID tag **200** to only broadcast in response to receiving an energizing electromagnetic transmission if the sensor **216** detects that the RFID tag **200** is accelerating, for example due to an item **103** (FIG. **1**A) to which the RFID tag **200** is attached being retrieved by a picker **100** (FIG. **1**A).

Each RFID tag **200** may include a corresponding unique identifier **223**. The unique identifier **223** allows for a one-to-one correspondence to be created between an RFID tag **200** and an associated item **103** (FIG. **1**A). In such embodiments, the unique identifier **223** may be globally unique, such as a serial number of the RFID tag **200**, or may correspond to a stock keeping unit (SKU) number for the item **103**, a universal product code (UPC) number for the item **103**, or other identifier of a type of item **103**. The unique identifier **223** may be used to facilitate tracking of items **103** within a fulfillment center, as will be further described herein.

With reference to FIG. **3**, shown is another embodiment in which RFID tags **200** (FIG. **2**A) may be used to verify that items **103** (FIG. **1**A) have been retrieved by a picker **100**. In embodiments such as those depicted in FIG. **3**, a picker **100**, such as an autonomous robot, moves an item storage structure **106** to an RFID reader station **300** within a fulfillment center. However, in some embodiments, the role of the RFID reader station **300** may be fulfilled by the RFID tag identification device **109** (FIG. **1**A) previously described. An

RFID reader **303** then reads the unique identifiers **223** (FIG. **2**B) of each RFID tag **200** (FIG. **2**A) attached to items **103** in the item storage structure **106**. The RFID reader station **300** may then send a list of the unique identifiers **223** of RFID tags **200** that responded to the RFID reader **303** to remote computing device. The remote computing device can then determine whether any items **103** are missing from the item storage structure **106** or whether any items **103** are within the item storage structure **106** that should not be present. For example, pickers **100** may retrieve the wrong item **103** from an item storage structure **106** when fulfilling an order, resulting in a mismatch between the items **103** that are expected to be present in the item storage structure **106** and the items **103** that the RFID reader **303** detects as actually present in the item storage structure **106**.

In some embodiments, the picker **100** may rotate the item storage location **106** to facilitate reading of the unique identifiers **223** (FIG. **3**) of each RFID tag **200** by the RFID reader **303**. Rotation of the item storage structure **106** relative to the RFID reader **303** may increase the number of RFID tags **200** which have their antennas **203** optimally aligned, during at least a portion of the rotation, to receive the radio waves broadcast from the RFID reader **303**. As the item storage structure **106** is rotated, RFID tags **200** which were not originally optimally aligned with respect to the RFID reader **303** for radio reception/transmission purposes may become optimally aligned during at least a portion of the rotation. This increases the number of RFID tags **200** which may be queried by the RFID reader **303**. In some embodiments, the picker **100** may rotate the item storage structure **106** at various speeds, shake the item storage structure **106**, or otherwise manipulate the item storage structure **106** to jostle RFID tags **200** into an optimal position to further increase the number of RFID tags **200** which may be queried. By increasing the number of RFID tags **200** placed in an optimal position for radio communication with the RFID reader **303**, the accuracy of identifying inventory within the item storage structure **106** may be increased.

Moving on to FIG. **4**, shown is a pictorial diagram of a fulfillment center **400**. A fulfillment center **400** is any materials handling facility where orders for items are fulfilled and/or shipments of items corresponding to orders originate. As such, a fulfillment center may, for example, correspond to a warehouse, a distribution center, a processing center, or a similar structure. In some embodiments, a fulfillment center **400** may be divided into multiple sections. For example, a fulfillment center **400** may include one or more inventory storage areas **403**, one or more sorting/packing areas **406**, and one or more loading areas **409** where shipments are loaded onto delivery vehicles for delivery to customers pursuant to orders for such items or other recipients such as other materials handling facilities. The fulfillment center **400** may also have one or more mechanisms or methods for moving items between sections, including conveyors, forklifts, robotic handling equipment, and other means. In addition, a fulfillment center **400** may have one or more pickers **100** (FIGS. **1** and **3**) or other employees who traverse pick routes or other paths generated by a shipment or order fulfillment system or process in order to retrieve items within the fulfillment center **400** for shipment. However, in some embodiments, a picker **100** may have items **103** delivered to the picker **100**, such as when robotic handling equipment or other devices move a shelving unit or other item storage structure **106** (FIG. **1**A) to a location near the picker **100**. Further, there may be one or more RFID reader stations **300** located throughout the inventory storage area **403** and/or the sorting/packing area **406**.

The inventory storage area **403** includes one or more item locations **413** where one or more items **103** (FIG. **1**A) may be located for short-term, long-term, piecewise or bulk storage in an item storage structure **106** (FIG. **1**A). An item storage structure **106** may correspond to any number of physical structures located at an item location **413**. For example, a shelf, set of shelves, a pallet on a floor, a bin and/or a series of bins, or similar structures may be considered to be an item storage structure **106** at an item location **413**.

Items **103** include physical goods available for order and shipment from the fulfillment center **400**. Items **103** may include, for example, books, compact discs (CDs), digital video discs (DVDs), televisions, cameras, stereo systems, computers, pots, pans, appliances, exercise equipment, power tools, garden tools, furniture, toys, clothes, cosmetics, medicine, medical supplies, jewelry, sporting goods and/or equipment, meat, fruit, vegetables, canned goods, dairy products, and/or other goods or products.

There is no requirement that identical items **103** be stored together at the same or neighboring item locations **413**. In some embodiments, it may be more efficient to organize the inventory storage area **403** such that identical or similar items **103** are stored together. For example, all DVDs may be stored in a group or cluster of adjacent item locations **413**, with all DVDs corresponding to a particular movie located in a single item location **413**. In other embodiments, it may be more efficient to store an item **103** in any item location **413** with sufficient capacity. In such embodiments, multiple instances of the same item **103** may be stored in separate item locations **413** at various locations, e.g., on opposite sides, of the inventory storage area **403**. For example, DVDs corresponding to a particular movie may be located in multiple item locations **413** spread through the inventory storage area **403** for more efficient accessibility in certain situations or scenarios.

The sorting/packing area **406** is where items **103** are sorted and packed for shipment. Within a sorting/packing area **406**, items **103** may be located at item locations **413** according to various embodiments of the present disclosure. Items **103** at item locations **413** within the sorting/packing area **406** may be located such that pickers may be able to quickly and efficiently retrieve items **103** for fulfillment or shipments. Generally, as items **103** within the item locations **413** of the sorting/packing area **406** are used to fulfill orders, items **103** at item locations **413** within the inventory storage area **403** may be automatically moved from the inventory storage area **403** to the sorting/packing area **406**. The automated movement of items from the inventory storage area **403** to the sorting/packing area **406** may be directed by automated systems or processes that track inventory levels at item locations **413** within the sorting/packing area **406** and dispatch employees or automatons to transfer goods from the item locations **413** within the inventory storage area **403** to the item locations **413** within the sorting/packing area **406**.

As orders for particular items **103** are received, one or more pickers **100** (FIGS. **1** and **3**) may be dispatched to retrieve one or more items **103** from item locations **413** within the sorting/packing area **406**. A single picker **100** may retrieve multiple items **103** of an order and one or more pickers **100** may be assigned to pick items **103** of the order. If items **103** are not at item locations **413** within the sorting/packing area **406**, or an insufficient quantity of items **103** are located within the sorting/packing area **406**, then the

pickers **100** may be dispatched to the inventory storage area **403** to retrieve the items **103** and deliver them to the sorting/packing area **406**. In some embodiments, pickers **100** may be designated employees at the fulfillment center **400** who retrieve items **103**. In other embodiments, pickers **100** may be machines, such as robots or other automatons that retrieve items **103** from the inventory storage area **403**.

Pickers **100** generally follow designated pick routes, which are generated to minimize the time and distance necessary for the picker **100** to travel to retrieve the requested items **103** from the item locations **413** within the sorting/packing area **406** or the inventory storage area **403**. For a given pick route, a picker **100** may retrieve one or more items **103** corresponding to one or more orders. The items **103** retrieved may be a number of different items **103** corresponding to one or more orders or the items **103** may be one or more of the same item **103** corresponding to one or more orders, depending on the requirements behind planning the pick route.

Referring next to FIG. **5**, shown is a flowchart that provides one example of the operation of a portion of the RFID tag identification device **109** according to various embodiments. It is understood that the flowchart of FIG. **5** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the RFID tag identification device **109** as described herein. As an alternative, the flowchart of FIG. **5** may be viewed as depicting an example of elements of a method implemented in the RFID tag identification device **109** according to one or more embodiments. Further, it is understood that some portions of the functionality depicted in FIG. **5** may be implemented on a remote computing device, such as a server, in those embodiments where additional computational capabilities are desired.

Beginning at box **503**, the RFID tag identification device **109** emits a radio wave from the RFID reader **113** (FIG. **1**A). The radio wave emitted by the RFID reader **113** energizes passive RFID tags **200** (FIG. **2**A) within a radius of the RFID reader **113** determined by the strength of the radio wave. In response to being energized by the radio wave, one or more of the RFID tags **200** may broadcast a response. In various embodiments, the strength of the radio wave emitted by the RFID reader **113**, and therefore the operational radius of the RFID reader **113**, may be adjustable. For example, a setting on the RFID tag identification device **109** may allow the strength of the emitted radio wave to be changed.

Proceeding to box **506**, the RFID tag identification device **109** determines whether one of the RFID tags **200** from which a signal is received is moving. The RFID tag identification device **109** may determine whether the RFID tag **200**, and by extension an item **103** (FIG. **1**A) to which the RFID tag **200** is attached, is moving using a number of approaches.

For example, the RFID tag **200** may include a sensor **216** (FIG. **2**B), such as an accelerometer, a MEMS gyroscope, or other motion detecting sensor. In such embodiments, the RFID tag **200** may transmit motion information, such as a velocity and/or acceleration of the RFID tag **200** or other motion information. The RFID tag identification device **109** may then use the transmitted motion information to determine if the RFID tag **200** is in motion. For example, if the RFID tag **200** reports a velocity or an acceleration with a non-zero value, then the RFID tag identification device **109** may determine that the RFID tag **200** is in motion.

However, in some embodiments related to this example, the RFID tag **200** may be configured to respond, when energized by an RFID reader such as the RFID reader **113** (FIG. **1**A) of the RFID tag identification device **109**, only if the sensor **216** detects a non-zero value for the velocity and/or the acceleration of the RFID tag **200**. In these or similar embodiments, configuring an RFID tag **200** to broadcast only if the sensor **216** detects that the RFID tag **200** is moving limits the number of RFID tags **200** transmitting in response to being energized by the RFID reader **113**. In such embodiments, step **506** may be unnecessary because only moving RFID tags **200** are broadcasting in response to being energized in step **503**.

Moving on to box **509**, if the RFID tag **200** is moving, the RFID tag identification device **109** processes the RFID tag **200**. Processing the motion data reported by the RFID tag **200** may include, for example, comparing the unique identifier **223** of the item **103** attached to the RFID tag **200** with a unique identifier **223** of an item **103** which a picker **100** is supposed to be retrieving from an item storage structure **106** to determine whether the picker **100** has retrieved the correct item **103**. In some embodiments, processing may also include determining whether the motion data of the RFID tag **200** matches expected motion data for an item **103** which a picker **100** is supposed to retrieve from an item storage structure **106**, as described in more detail with respect to FIG. **7**.

Referring to box **513**, if the RFID tag **200** is not moving, the RFID tag identification device **109** marks the RFID tag **200** as having been processed and excludes the RFID tag **200** from further processing. Because multiple RFID tags **200** may have been energized at box **503** and transmitted a response, ignoring and/or excluding RFID tags **200** from further processing that do not report movement data allows the RFID tag identification device **109** to isolate individual RFID tags **200** having associated movement.

Proceeding to box **516**, the RFID tag identification device **109** determines whether any additional energized RFID tags **200** within range have broadcast a response but have not yet been processed. If additional RFID tags **200** remain to be processed, then execution loops back to box **506** and the RFID tag identification device **109** processes the next RFID tag **200**. If there are no additional RFID tags **200** to be processed, then execution ends.

Referring next to FIG. **6**, shown is a flowchart that provides one example of the operation of a portion of the RFID tag identification device **109** according to various embodiments. It is understood that the flowchart of FIG. **6** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the RFID tag identification device **109** as described herein. As an alternative, the flowchart of FIG. **6** may be viewed as depicting an example of elements of a method implemented in the RFID tag identification device **109** according to one or more embodiments. Further, it is understood that some portions of the functionality depicted in FIG. **6** may be implemented on a remote computing device, such as a server, in those embodiments where additional computational capabilities are desired.

Beginning at box **603**, the RFID tag identification device **109** emits a radio wave from the RFID reader **113** (FIG. **1**A). The radio wave emitted by the RFID reader **113** energizes passive RFID tags **200** (FIG. **2**A) within a radius of the RFID reader **113** determined by the strength of the radio wave. In response to being energized by the radio wave, one or more of the RFID tags **200** may broadcast a response. In various embodiments, the strength of the radio wave emitted by the RFID reader **113**, and therefore the operational radius

of the RFID reader **113**, may be adjustable. For example, a setting on the RFID tag identification device **109** may allow the strength of the emitted radio wave to be changed.

Proceeding next to box **606**, the RFID tag identification device **109** may use a signal strength meter **116** to identify RFID tags **200** that are in motion, based upon measured changes in the signal strength of the responses of individual RFID tags **200** over an interval or period of time. For example, an RFID tag **200** may broadcast its unique identifier **223** several times over the course of a second. The signal strength meter **116** may be used to determine whether there was a change in the signal strength of each broadcast, as well as the magnitude of such a change between each broadcast.

Moving on to box **609**, the RFID tag identification device **109** may determine whether a change in the signal strength of a broadcast by an RFID tag **200** occurred. The determination may be based on a single comparison between two broadcasts by the RFID tag **200** at two points in time. However, in some embodiments, the determination may be based on a series of measurements of signal strengths corresponding to multiple broadcasts by the RFID tag **200** over a period of time. For example, to account for environmental factors, RFID tag identification device **109** may use the slope or the value of derivative function of a trend line, trend curve, and/or similar graph, representing the series of measurements of signal strengths of the broadcasts of the RFID tag **200** to determine whether a change in the signal strength occurred and whether the signal strength was increasing or decreasing over time.

Referring next to box **613**, if a change in the signal strength of the broadcast by the RFID tag **200** has occurred, the RFID tag identification device **109** processes the RFID tag **200**. Processing the RFID tag **200** may include, for example, determining the type of motion associated with the RFID tag **200** and taking an appropriate course of action. For example, the RFID tag identification device **109** may determine that the RFID tag **200** is moving towards the RFID tag identification device **109** based at least in part on identifying an increase in the signal strength broadcast by the RFID tag **200**. The RFID tag identification device **109** may therefore conclude that because the RFID tag **200** is moving towards the RFID tag identification device **109**, an item **103** (FIG. **1**A) attached to the RFID tag **200** has been retrieved by a picker **100** (FIG. **1**A). Accordingly, the RFID tag identification device **109** may compare the unique identifier **223** (FIG. **2**B) of the item **103** attached to the RFID tag **200** with a unique identifier **223** of an item **103** which a picker **100** is supposed to be retrieving from an item storage structure **106** to determine whether the picker **100** has retrieved the correct item **103**. In some embodiments, processing may also include determining whether the change in the signal strength of the RFID tag **200** matches an expected change in the signal strength for an item **103** which a picker **100** is supposed to retrieve from an item storage structure **106**, as described in more detail with respect to FIG. **7**.

However, with respect to box **616**, if a change in the signal strength of the broadcast by the RFID tag **200** has not occurred, the RFID tag identification device **109** marks the RFID tag **200** as having been processed and excludes the RFID tag **200** from further processing. Because multiple RFID tags **200** may have been energized at box **603** and transmitted a response, ignoring and/or excluding RFID tags **200** from further processing that are not moving, as indicated by a lack of a change in signal strength detected by the signal strength meter **116**, allows the RFID tag identification device **109** to isolate individual RFID tags **200** having associated movement.

Proceeding to box **619**, the RFID tag identification device **109** determines whether any additional energized RFID tags **200** within range have broadcast a response but have not yet been processed. If additional RFID tags **200** remain to be processed, then execution loops back to box **609** and the RFID tag identification device **109** determines whether the next RFID tag **200** showed changes in the broadcast signal strength. If there are no additional RFID tags **200** to be processed, then execution ends.

It should be noted that the approaches depicted in the flowcharts of FIGS. **5** and **6** are not mutually exclusive. In some embodiments, data from a sensor **216** and a signal strength meter **116** may be used in conjunction. For example, use of the approach depicted in FIG. **5** in combination with the approach depicted in FIG. **6** may result in greater accuracy in comparison to using either approach individually.

Referring next to FIG. **7**, shown is a flowchart that provides one example of the operation of a portion of the RFID tag identification device **109** according to various embodiments. It is understood that the flowchart of FIG. **7** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the RFID tag identification device **109** as described herein. As an alternative, the flowchart of FIG. **7** may be viewed as depicting an example of elements of a method implemented in the RFID tag identification device **109** according to one or more embodiments. Moreover, the functionality or method depicted in FIG. **7** may also, in some embodiments, be implemented by various RFID reader stations **300** (FIG. **3**) located throughout a fulfillment center **400** (FIG. **4**) in order to monitor items **103** (FIG. **1**A) within the fulfillment center **400**.

Beginning with box **703**, the RFID tag identification device **109** determines a trajectory of an energized RFID tag **200** (FIG. **2**A). Because an RFID reader, such as the RFID reader **113** (FIG. **1**A) of a RFID tag identification device **109**, may energize multiple RFID tags **200** within the broadcast range of the RFID reader **113**, the RFID tag identification device **109** may use one or more techniques to determine a trajectory of individual RFID tags **200** in order to filter extraneous responses. Some embodiments may make use of information transmitted from a sensor **216** of an RFID tag **200**, such as those embodiments previously described in FIG. **5**. Other embodiments may make use of a signal strength meter **116** (FIG. **1**A) of the RFID tag identification device **109**, such as those embodiments previously described in FIG. **6**. In some embodiments, a combination of approaches may be used.

Proceeding to box **706**, the RFID tag identification device **109** determines whether the trajectory determined in box **703** matches a previously defined trajectory profile. Different trajectory profiles may define different scenarios related to the movement of an RFID tag **200**. For example, a trajectory profile may include an expected trajectory corresponding to one or more of a number of various scenarios. The expected trajectory may represent an expected speed, direction of motion, duration of movement, series and/or sequence of positions, and other such data. The expected trajectory may also represent an expected series and/or sequence of signal strengths to be measured by the signal strength reader **116** (FIG. **1**A). By matching data related to the motion of a particular RFID tag **200** to a previously defined trajectory profile, the RFID tag identification device

109 can determine what is happening to the particular RFID tag 200. If the determined trajectory matches a previously defined trajectory profile, execution proceeds to box 709. If the determined trajectory does not match a previously defined trajectory profile, then execution instead proceeds to box 713.

For example, the direction in which a picker 100 moves an item 103 from an item storage structure 106 (FIG. 1A) and the speed at which such an item 103 moves, or a corresponding sequence of signal strength measurements, may be previously known from previous measurements or other sources. This data may be stored in a trajectory profile. If the RFID tag identification device 109 determines that an RFID tag 200 associated with an item 103 is moving at the same speed and in the same direction as those indicated in a trajectory profile matching that of a picker 100 retrieving an item 103 from an item storage structure 106, or that the sequence of signal strength measurements matches the sequence of signal strength measurements anticipated from a picker 100 retrieving an item 103 from an item storage structure 106, then the RFID tag identification device 109 may determine that the picker has retrieved an item 103 from the item storage structure 106. As previously described, execution would then proceed to box 709 in such a scenario.

As another example, if the RFID tag identification device 109 determines that an RFID tag 200 associated with an item 103 in the item storage structure 106 is accelerating and moving towards the ground, the RFID tag identification device 109 may determine that the RFID tag 200 has fallen off of the item 103 or that the item 103 itself has fallen from the item storage structure 103. If the detected fall occurs at the same time as the picker 100 is attempting to retrieve the item from the item storage structure 106, the RFID tag identification device 109 may further determine that either the item 103 was dropped by the picker 100 or that the item 103 dislodged from the item storage structure 106, depending upon which trajectory profile better matches the data. As previously described, execution would then proceed to box 709 in such a scenario.

Proceeding to box 709, the RFID tag identification device 109 reports the RFID tag 200 to a remote computing device, such as a server, based on the type of trajectory profile that the RFID tag 200 was determined to have matched in box 706. For example, if the trajectory of the RFID tag 200 is determined to have matched the trajectory of a picker 100 retrieving an item 103 from an item storage structure 106, then the RFID tag identification device 109 may report that the item 103 corresponding to the RFID tag 100 has been picked. As another example, if the trajectory of the RFID tag 200 is determined to have matched the trajectory of an item 103 falling from the item storage structure 106, such as an item 103 falling off of a shelf, then the RFID tag identification device 109 may report the fallen item 103 to an appropriate system, application, or individual. As yet another example, the RFID tag identification device 109 may determine that the trajectory or sequence of signal strength readings indicates that an item 103 is moving outside of the fulfillment center 400 and report the item 103 as being potentially stolen. As further illustrative example, the RFID tag identification device 109 may determine that the motion data, trajectory, or series of signal strength readings matches motions, trajectories, or signal strength measurements corresponding to various aspects of order fulfillment, such as sorting or packing items 103 for shipment, loading items 103 onto delivery vehicles for shipment, and/or other activities.

Referring to box 713, if the determined trajectory does not match a previously defined trajectory profile, the RFID tag identification device 109 sends an error code, exception, or similar message to a remote computing device. For example, the RFID tag identification device 109 may, in some embodiments, send an error message to a remote computing device or remotely executing application. The message may contain, for example, the motion data measured by the signal strength meter 116 or the motion data reported by the RFID tag 200, as well as an indication that the motion data does not match a known trajectory profile. Execution would then proceed to box 716.

Moving on to box 716, the RFID tag identification device 109 determines whether additional RFID tags 200 remain to be processed. If additional RFID tags 200 remain to be processed, execution loops back to box 703 and the trajectory of the next RFID tag 200 to be analyzed is determined. If no additional RFID tags 200 remain to be processed, then execution ends.

With reference to FIG. 8, shown is a networked environment 800 according to various embodiments. The networked environment 800 includes a computing environment 803 and a client device 806, which are in data communication with each other via a network 809. The network 809 includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, or other suitable networks, etc., or any combination of two or more such networks. For example, such networks may comprise satellite networks, cable networks, Ethernet networks, and other types of networks.

The computing environment 803 may comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment 803 may employ a plurality of computing devices that may be arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment 803 may include a plurality of computing devices that together may comprise a hosted computing resource, a grid computing resource and/or any other distributed computing arrangement. In some cases, the computing environment 803 may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

Various applications and/or other functionality may be executed in the computing environment 803 according to various embodiments. Also, various data is stored in a data store 813 that is accessible to the computing environment 803. The data store 813 may be representative of a plurality of data stores 813 as can be appreciated. The data stored in the data store 813, for example, is associated with the operation of the various applications and/or functional entities described below.

The components executed on the computing environment 803, for example, include a tracking application 816 as well as other applications, services, processes, systems, engines, or functionality not discussed in detail herein. The tracking application 816 is executed to determine whether items 103 in pick lists 819 have been retrieved from inventory 826 at appropriate item locations 413, as well as track the movements of items 103 based on their corresponding RFID tags 200 (FIG. 2). The tracking application 816 may make these determinations based at least in part on information supplied by client devices 806, such as RFID readers 113 (FIG. 1A)

and/or signal strength meters **116** (FIG. **1**A) that may be included in RFID tag identification devices **109** (FIG. **1**A) or RFID reader stations **300** (FIG. **3**).

The data stored in the data store **813** includes, for example, data related to pick lists **819**, orders **823**, data related to fulfillment centers **400**, and potentially other data. For each fulfillment center **400**, the data store **813** may also store data related to an inventory **826** of items **103** at each fulfillment center **400**, the item locations **413** in each fulfillment center **400** where one or more items **103** of inventory may be stored, and data related to RFID tags **200** associated with individual items **103** of inventory **826**, such as the unique identifier **223** for each RFID tag **200** used at a fulfillment center **400**. For each pick list **819**, the data store **813** may also track or store information related to items **103** included in the pick list **819**.

A pick list **819** includes a list of items **103** to be retrieved from the inventory **826** of a fulfillment center **400** by a picker **100** (FIG. **1**A). The pick list **819** may include one or more items **103** to be retrieved from inventory **826**. The items **103** included in the pick list **819** may correspond to one or more orders **823**. In some embodiments, the pick list **819** may also include the item location **413** for each item **103** in the pick list **819**, a unique identifier **223** of an RFID tag **200** corresponding to an item **103** in the pick list **819**, a route between item locations **413** of the items **103** to be retrieved, and/or potentially other data.

Orders **823** are representative of one or more customer orders **823** placed through an electronic commerce application for purchase and/or lease of one or more items **103**. Individual orders **823** may correspond to a single pick list **819** or multiple pick lists **819**, each of which may contain one or more items **103** included in the order **823**. Further, individual orders **823** may be fulfilled from one or more fulfillment centers **400**. For example, a customer may place an order **823** for three items **103**. The first item **103** may be shipped from a first fulfillment center **400** and the remaining two items **103** may be shipped from a second fulfillment center **400**. Further, the two items **103** shipped from the second fulfillment center **400** may be included in a single pick list **819** for retrieval by a single picker **100** or may be included in different pick lists **819** for simultaneous or near simultaneous retrieval by two pickers **100**.

The client device **806** is representative of any one or more of a plurality of client devices that may be coupled to the network **809**, such as RFID reader stations **300** (FIG. **3**), RFID tag identification devices **109** (FIG. **1**A), or other computing devices that implement similar functionality. For example, the client device **806** may include a processor-based system such as a computer system. The client device **806** may include a display. The display may comprise, for example, one or more devices such as liquid crystal display (LCD) displays, gas plasma-based flat panel displays, organic light emitting diode (OLED) displays, electrophoretic ink (E ink) displays, LCD projectors, or other types of display devices, etc.

The client device **806** may be configured to execute various applications. These applications may be executed in a client device **806**, for example, to access content served by the computing environment **803** and/or other servers, thereby rendering a user interface on the display. To this end, the client application may comprise, for example, a browser, a dedicated application, etc., and the user interface may comprise a network page, an application screen, etc. Client applications may also be executed to submit data to the tracking application **816** or other applications executing in the computing environment **803**. In some embodiments, the client device **806** may be further configured to execute applications beyond the client application such as, for example, email applications, social networking applications, word processors, spreadsheets, and/or other applications.

Next, a general description of the operation of the various components of the networked environment **800** is provided. To begin, the tracking application **816** receives a unique identifier **223** of an RFID tag **200** from a client device **806**, such as a RFID tag identification device **109** attached to a picker **100**. The tracking application **816** then determines whether the unique identifier **223** of the RFID tag **200** corresponds to an item **103** in a pick list **819** associated with the picker **100**. If the tracking application **816** determines that the unique identifier **223** received from the client device **806** matches a unique identifier **223** of an item **103** in a pick list **819** assigned to the picker **100**, then the tracking application **816** marks the item **103** in the pick list **819** and/or the order **823** as having been retrieved by the picker **100**. However, if the unique identifier **223** received from the client device **806** does not match the unique identifier **223** of the item **103** in the pick list **819**, then the tracking application **816** sends an error message to the client device **806**. The error message may notify the picker **100** that the wrong item **103** at the item location **413** has been retrieved. In some embodiments, the error message may contain additional instructions for the picker **100**, such as the name and description of the item **103** to be retrieved from the item location **413** and/or other information.

In another embodiment, the tracking application **816** receives a plurality of unique identifiers **223** corresponding to a plurality of RFID tags **200** for individual items **103** of inventory **826** located at a particular item location **413**. The plurality of unique identifiers **223** for the plurality of RFID tags **200** may, for example, be transmitted from a client device **806**, such as an RFID reader station **300** (FIG. **3**). The tracking application **816** then compares each of the received unique identifiers **223** with those unique identifiers **223** stored in association with the particular item location **413**. If the tracking application **816** detects a mismatch, then the tracking application **816** may send an error message to an inventory management system or may initiate other types of corrective action.

A mismatch may result from a number of conditions. A mismatch may, for example, occur when a unique identifier **223** for an item **103** is reported as not being present at the particular item location **413** when the information stored in the data store **813** indicates that the item **103** corresponding to the unique identifier **223** at issue should be present at the particular item location **413**. A mismatch may also occur, for example, when a unique identifier for an item **103** is reported as being present at the particular item location **413** when the information stored in the data store **813** indicates that the item **103** corresponding to the unique identifier **223** at issue should not be present at the particular item location **413**.

Referring next to FIG. **9**, shown is a flowchart that provides one example of the operation of a portion of the tracking application **816** according to various embodiments. It is understood that the flowchart of FIG. **9** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the tracking application **816** as described herein. As an alternative, the flowchart of FIG. **9** may be viewed as depicting an example of elements of a method implemented in the computing environment **803** (FIG. **8**) according to one or more embodiments.

Beginning with box **903**, the tracking application **816** receives a unique identifier **223** (FIG. **2**B) from a client

device **806** (FIG. **8**) in proximity to a picker **100** (FIG. **1**A), such as a RFID tag identification device **109** (FIG. **1**A). For example, the RFID tag identification device **109** may have selected a unique identifier **223** of an RFID tag **200** in response to determining that the RFID tag **200** is moving, as previously described in FIGS. **5** and **6**.

Proceeding to box **906**, the tracking application **816** determines whether the unique identifier **223** received from the client device **806** matches a unique identifier **223** for an item **103** in a pick list **819**. If the unique identifier **223** received from the client device **806** matches a unique identifier **223** for an item **103** in the pick list **819**, then execution proceeds to box **909**. If the unique identifier **223** received from the client device **806** does not match a unique identifier **223** for an item **103** in the pick list **819**, then execution proceeds to box **913**.

Moving on to box **909**, the tracking application **816** marks the item **103** corresponding to the unique identifier **223** as having been retrieved or "picked." In some embodiments, this may include modifying appropriate records stored in association with the appropriate pick list **819**, order **823** (FIG. **8**), and/or inventory **826** (FIG. **8**) of the appropriate fulfillment center **400** (FIG. **4**). Execution subsequently ends.

Referring next to box **913**, the tracking application **816** sends an error message to the client device **806**. The error message may, for example, indicate to the picker **100** that the wrong item **103** has been retrieved from the item location **413**. In some embodiments, the error message may further instruct the picker **100** to retrieve the correct item **103**. In such embodiments, the error message may also, for example, include a description of the correct item **103** to be retrieved. The description may, in some embodiments, include an image of the correct item **103** to be retrieved. Execution subsequently ends.

Referring next to FIG. **10**, shown is a flowchart that provides one example of the operation of a portion of the tracking application **816** according to various embodiments. It is understood that the flowchart of FIG. **10** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the tracking application **816** as described herein. As an alternative, the flowchart of FIG. **10** may be viewed as depicting an example of elements of a method implemented in the computing environment **803** (FIG. **8**) according to one or more embodiments.

Beginning with box **1003**, the tracking application **816** identifies an item storage structure **106** (FIG. **3**) that is to have its contents verified. The item storage structure **106** may be selected, for example, as part of a routine inventory audit or in response to a previously detected inventory discrepancy involving the item storage structure **106**.

Referring next to box **1006**, the tracking application **816** directs a picker **100** (FIG. **3**) to move the item storage structure **106** to an RFID reader station **300** (FIG. **3**) and to subsequently rotate the item storage structure **106** in the vicinity of the RFID reader station **300** in a manner similar to that depicted in FIG. **3**. As previously discussed, the picker **100** may be, for example, an autonomous robot or an employee equipped, for example, with a hand truck, dolly, forklift, or other device appropriate for moving and manipulating a particular item storage structure **106**.

Moving on to box **1009**, the tracking application **816** receives one or more unique identifiers **223** (FIG. **2**B) from a client device **806** (FIG. **8**) in proximity to a picker **100** (FIG. **3**), such as an RFID reader station **300** in response to the picker **100** rotating the item storage structure **106** in the vicinity of the RFID reader station **300**. The one or more unique identifiers **223** represent those items **103** (FIG. **8**) located at a particular item storage location **413** (FIG. **8**).

Proceeding to box **1013**, the tracking application **816** determines whether the received unique identifiers **223** match the unique identifiers **223** (FIG. **8**) for items **103** (FIG. **8**) that are expected to be located in the item storage structure **106** at the item storage location **413**. When a large number of unique identifiers **223** are received, such as from RFID tags **200** (FIG. **2**) in multiple item storage structures within range of the RFID reader **303** (FIG. **3**) of the RFID reader station **300**, the tracking application **816** may first filter the received unique identifiers **223**. For example, the RFID reader **303** may energize RFID tags **200** of items **103** in the item storage structure **106** as well as RFID tags **200** of items **103** in nearby item storage structures **106**. However, because the tracking application **816** has directed a picker **100** to rotate a single item storage structure **106** in proximity to the RFID reader station **300**, the tracking application **816** may select only those unique identifiers **223** that are associated with RFID tags **200** that are in motion. Whether an RFID tag **200** is in motion may be determined using one or more of the approaches previously discussed in FIG. **5** and FIG. **6**. In the event that multiple item storage structures **106** are in motion, such as when a second picker **100** is moving a nearby item storage structure **106** past the rotating item storage structure **106**, the tracking application **816** may use approaches, such as those previously described in FIG. **7**, to identify the unique identifiers **223** of RFID tags **200** that are rotating in a circular motion. In such embodiments, the tracking application **816** compares the unique identifiers **223** of the filtered RFID tags **200** with unique identifiers **223** of items **103** expected to be located in the item storage structure **106**. If the tracking application **816** determines that there is a mismatch between the received unique identifiers **223** and the unique identifiers **223** representing items **103** that are expected to be located in the item storage structure **106**, then execution proceeds to box **1016**. If no mismatch exists, then execution proceeds to box **1019**.

Referring next to box **1016**, the tracking application **816** sends an error message to an inventory management system, inventory control system, and/or similar system that may initiate a process to correct the mismatch. The message may, for example, include the details such as a list of items **103** that were not reported as being present in the item storage structure **106** at the item location **413** or a list of items **103** that were reported as being present in the item storage structure **106** at the item location **413** but should not have been. Mismatches may indicate, for example, that an item **103** was incorrectly retrieved to fulfill an order **823** at some point previously, that an item **103** was incorrectly recorded as being stored at a particular item location **413**, that an item **103** may have been stolen, and/or other scenarios. Execution subsequently ends.

However, proceeding to box **1019**, the tracking application **816** confirms that unique identifiers **223** of RFID tags **200** (FIG. **2**) of items **103** detected in the item storage structure **106** at the item location **413** match the set of expected unique identifiers **223**. Confirmation may involve marking individual items **103** in the inventory **826** of a fulfillment center **400** as present or "in inventory" at a specific data and/or time. Confirmation may also involve sending a message to an inventory management system, inventory control system, and/or similar system with a notification that item **103** is present in the inventory **826** as expected.

With reference to FIG. **11**, shown is a schematic block diagram of the computing environment **803** according to an embodiment of the present disclosure. The computing environment **803** includes one or more computing devices **1100**. Each computing device **1100** includes at least one processor circuit, for example, having a processor **1103** and a memory **1106**, both of which are coupled to a local interface **1109**. To this end, each computing device **1100** may comprise, for example, at least one server computer or like device. The local interface **1109** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **1106** are both data and several components that are executable by the processor **1103**. In particular, stored in the memory **1106** and executable by the processor **1103** are the tracking application **816** and/or potentially other applications. Also stored in the memory **1106** may be a data store **813** and other data. In addition, an operating system may be stored in the memory **1106** and executable by the processor **1103**.

It is understood that there may be other applications that are stored in the memory **1106** and are executable by the processor **1103** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective-C®, Java®, JavaScript®, Perl®, PHP®, Visual Basic®, Python®, Ruby®, Flash®, or other programming languages.

A number of software components are stored in the memory **1106** and are executable by the processor **1103**. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor **1103**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **1106** and run by the processor **1103**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **1106** and executed by the processor **1103**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **1106** to be executed by the processor **1103**, etc. An executable program may be stored in any portion or component of the memory **1106** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, USB flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **1106** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory **1106** may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, and/or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may comprise, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may comprise, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **1103** may represent multiple processors **1103** and/or multiple processor cores and the memory **1106** may represent multiple memories **1106** that operate in parallel processing circuits, respectively. In such a case, the local interface **1109** may be an appropriate network that facilitates communication between any two of the multiple processors **1103**, between any processor **1103** and any of the memories **1106**, or between any two of the memories **1106**, etc. The local interface **1109** may comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **1103** may be of electrical or of some other available construction.

Although the tracking application **816**, portions of the RFID tag identification device **109** (FIG. **1**A), portions of the RFID tag **200** (FIGS. **2**A and **2**B), and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowcharts of FIGS. **9** and **10** show the functionality and operation of an implementation of portions of the tracking application **816**, while the flowcharts of FIGS. **5**, **6**, and **7** show the functionality and operation of an implementation of portions of the RFID tag identification device **109** and/or the RFID reader station **300**. If embodied in software, each block may represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that comprises human-readable statements written in a programming language or machine code that comprises numerical instructions recognizable by a suitable execution system such as a processor **1103** in a computer system or other system. The machine code may be converted from the source code, etc. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

Although the flowcharts of FIGS. **5**, **6**, **7**, **9** and **10** show a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIGS. **5**, **6**, **7**, **9** and **10** may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIGS. **5**, **6**, **7**, **9** and **10** may be skipped or omitted. In addition, any number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

Also, any logic or application described herein, including the tracking application **816** and various portions of the RFID tag identification device **109**, RFID reader station **300**, and/or RFID tag **200** (FIG. **2**A), that comprises software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **1103** in a computer system or other system, portions of a RFID tag identification device **109**, RFID reader station **300** and/or a microchip **206** in an RFID tag **200**. In this sense, the logic may comprise, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can comprise any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

Further, any logic or application described herein, including the tracking application **816**, portions of the RFID tag identification device **109**, portions of the RFID reader station **300**, and/or the RFID tag **200**, may be implemented and structured in a variety of ways. For example, one or more applications described may be implemented as modules or components of a single application. Further, one or more applications described herein may be executed in shared or separate computing devices or a combination thereof. For example, a plurality of the applications described herein may execute in the same computing device **1100**, or in multiple computing devices in the same computing environment **803**. Additionally, it is understood that terms such as "application," "service," "system," "engine," "module," and so on may be interchangeable and are not intended to be limiting.

Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

What is claimed is:

1. A system, comprising:

a robotic picker configured to move an item storage structure containing a plurality of items, wherein individual ones of the plurality of items have a radio frequency identification (RFID) tag affixed; and

an RFID tag identification device configured to:

energize a plurality of RFID tags affixed to respective ones of the plurality of items;

receive a respective plurality of responses from respective ones of the plurality of RFID tags, each of the respective plurality of responses from the respective ones of the plurality of RFID tags comprising velocity data for the respective ones of the plurality of RFID tags;

determine that a particular RFID tag within the plurality of RFID tags is in motion based at least in part on the velocity data in a respective response received from the particular RFID tag; and

determine an identifier for the particular RFID tag.

2. The system of claim **1**, wherein, to determine that the particular RFID tag is in motion, the RFID tag identification device is further configured to receive acceleration data from the particular RFID tag, wherein the acceleration data indicates that the particular RFID tag is moving.

3. The system of claim **1**, wherein, to determine that the particular RFID tag is in motion, the RFID tag identification device is further configured to detect a change in an electric field strength of the particular RFID tag.

4. The system of claim **1**, wherein:

the RFID tag identification device further comprises an RFID reader; and

the robotic picker is further configured to rotate the item storage structure in place within range of the RFID reader.

5. The system of claim **1**, wherein the identifier comprises a first identifier and the system further comprises a computing device in network communication with the RFID tag identification device, the computing device comprising a processor, a memory, and machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to determine that the first identifier for the particular RFID tag matches a second identifier of an item located in the item storage structure.

6. The system of claim **1**, wherein the identifier is a first identifier and the system further comprises a computing device in network communication with the RFID tag identification device, the computing device comprising a processor, a memory, and machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to determine that the first identifier for the particular RFID tag matches a second identifier of an item included in a pick list associated with the robotic picker.

7. A system, comprising:

a robotic picker configured to move an item storage structure containing a plurality of items, wherein individual ones of the plurality of items have a radio frequency identification (RFID) tag affixed; and

an RFID tag identification device configured to:

energize a plurality of RFID tags comprising the plurality of RFID tags affixed to respective ones of the plurality of items;

receive a respective plurality of responses from respective ones of the plurality of RFID tags, each of the respective plurality of responses including acceleration data for the respective ones of the plurality of RFID tags, wherein the acceleration data indicates whether the respective ones of the plurality of RFID tags are in motion;

determine that a particular RFID tag within the plurality of RFID tags is in motion based at least in part on the acceleration data included in a respective response received from the particular RFID tag;

determine a first identifier for the particular RFID tag; and

send the first identifier to a computing device; and

the computing device being in network communication with the RFID tag identification device, wherein the computing device comprises a processor, a memory, and machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to determine that the first identifier for the particular RFID tag matches a second identifier for an item on a pick list.

8. The system of claim **7**, wherein the pick list is associated with the robotic picker.

9. The system of claim **8**, wherein, to determine that the particular RFID tag is in motion, the RFID tag identification device is further configured to receive velocity data from the particular RFID tag, wherein the velocity data indicates that the particular RFID tag is moving.

10. The system of claim **9**, wherein:

the RFID tag identification device further comprises an RFID reader; and

the robotic picker is further configured to rotate the item storage structure in place within range of the RFID reader.

11. The system of claim **7**, wherein, to determine that the particular RFID tag is in motion, the RFID tag identification device is further configured to detect a change in an electric field strength of the particular RFID tag.

12. The system of claim **7**, wherein:

the RFID tag identification device further comprises an RFID reader; and

the robotic picker is further configured to rotate the item storage structure around the RFID reader.

13. The system of claim **7**, wherein the machine readable instructions of the computing device, when executed by the processor, further cause the computing device to determine that the item in the pick list is located in the item storage structure based at least in part on a match of the first identifier to the second identifier.

14. A method, comprising:

moving, with a robotic picker, an item storage structure within range of a radio frequency identification (RFID) tag reader, wherein the item storage structure comprises a plurality of items and individual ones of the plurality of items have an RFID tag affixed;

emitting, from a RFID tag reader, an electric field;

moving, with the robotic picker, the item storage structure while the RFID tag reader emits the electric field;

receiving, with an RFID tag identification device, responses from a plurality of energized RFID tags affixed to the plurality of items;

detecting, with the RFID tag identification device, a change in an electric field strength of each one of the plurality of energized RFID tags affixed to the plurality of items;

determining, with the RFID tag identification device, that a particular energized RFID tag from the plurality of energized RFID tags is in motion based at least in part on the change in the electric field strength of the particular energized RFID tag; and

selecting, with the RFID tag identification device, an identifier broadcast by the particular energized RFID tag that is in motion.

15. The method of claim **14**, further comprising determining that an item is located within the item storage structure based at least in part on the identifier broadcast by particular energized RFID tag that is in motion.

16. The method of claim **14**, wherein determining that the particular energized RFID tag is in motion further comprises receiving velocity data from the particular energized RFID tag, wherein the velocity data indicates that the particular energized RFID tag is moving.

17. The method of claim **14**, wherein determining that the particular energized RFID tag is in motion further comprises receiving acceleration data from the particular energized RFID tag, wherein the acceleration data indicates that the particular energized RFID tag is moving.

18. The method of claim **14**, wherein moving the item storage structure while the RFID tag reader emits the electric field further comprises rotating in place, with the robotic picker, the item storage structure.

19. The method of claim **14**, wherein moving the item storage structure while the RFID tag reader emits the electric field further comprises moving, with the robotic picker, the item storage structure around the RFID tag identification device.

20. The method of claim **14**, further comprising sending, from the RFID tag identification device, the identifier to a remote computing device to determine that at least one of the plurality of items associated with the particular energized RFID tag is included in a pick list.

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